(12) INTERNATIONAL REQUEST PUBLISHED BY VIRTUE OF THE TREATY FOR COOPERATION ON PATENTS (PCT)

(19) World Organization for Intellectual Property
International Office

(43) Date of International Publication:
August 12, 2004

(10) International Publication Number:
WO 2004/068394 A1

(51) International patent classification[7]: **GO6K 9/00**

(21) Number of International Application: PCT//FR2004/000093

(30) Data relative to priority:
03/00593 January 21, 2003 FR

(71) Filer (*for all designated states except US*): ATMEL GRENOBLE S.A. [FR/FR]; Avenue de Rochepleine, F-38120 Saint Egrève (FR)

(72) Inventor;

(75) Inventor/Filer (*for the US only*): Jean-François MAINGUET [FR/FR]; Thales Intellectual Property, 31-33, avenue Aristide Briand, F-94117 Arcueil Cedex (FR).

(73) Agents: Michel GUERIN etc.: 31-33, avenue Aristide Briand, F-94117 Arcueil Cedex (FR).

(81) Designated states (*unless otherwise indicated, for all available titles of national protection*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, EC, EE, EG, ES, FL, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated states (*unless otherwise indicated, for all available titles of regional protection*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

-- *report on international research*

-- *before delay provided for the modification of claims expires, will be republished if modifications are received*

For two-letter codes and other abbreviations, refer to "Explanatory Notes Relative to Codes and Abbreviations" (Notes explicatives relatives aux codes et abréviations") found at the beginning of each regular issue of the "Gazette du PCT".

(54) Title: Person Recognition Method and Device

Figure 1

(57) Abstract: The invention relates to the recognition of persons by biometric identification systems. According to the invention, an optical or non-optical sensor (10) sensing an image of a fingerprint (theoretically on a silicon chip) associated with spectral recognition of the skin is used to recognize persons with the aid of fewer light-emitting elements (12) (generally LED light-emitting diodes) than those used for spectral recognition alone. The fingerprint image sensor and a sensor (12.14) sensing spectral transmission information relating to the skin of the finger are disposed on a common base, said fingerprint being captured by the image sensor.

PERSON RECOGNITION METHOD AND DEVICE

The invention concerns human biometric recognition devices destined for applications in which a high level of security is necessary to protect against the risk of fraud and in which the physical presence of a designated person and the identification of this person are necessary to limit risk.

The invented device uses a digital fingerprint image sensor. Such a digital fingerprint image sensor is achieved by using an integrated circuit, in principal silicon-based, made up of a matrix of individual sensing elements that permit establishment of a representation of the image of the fingerprint of a finger placed directly or indirectly on the surface of the matrix. The detection of the fingerprint is generally optical or capacitive or thermal or piezoelectric and the sensitive elements of the sensor are thus sensitive, respectively, to light, to the capacitive proximity, or to heat, or to pressure.

Some sensors function in the presence of a stationary finger placed on the surface of a sensor, the active matrix of which is rectangular or square; in this case, the surface of the sensor has a total size corresponding to the surface of the fingerprint to be detected; other sensors function by sliding the finger on a sensor which has a detection matrix - with a surface much smaller than the fingerprint to be detected - that is an elongated bar of several rows of isolated detectors (or even a single row).

The known techniques for capturing a digital fingerprint do not allow detection of whether the finger is alive; one can deceive the sensor by using a molded fake finger, but one can also glue onto a real finger a thin layer of a plastic material on which a copy of a fingerprint has been molded; one can also deceive the sensor - and this fraud is almost impossible to detect -- with a severed finger, which has a physiology that is extremely close to that of a finger connected normally to the body from which it originated.

A detection technique using two electrodes and measuring the conductivity or impedance of the finger has already been proposed, but this is easily deceived by wetting a fake plastic finger with saliva

or by using a conductive malleable material, for example an aluminum foil applied to the fake finger. This technique cannot be very precise because the usage conditions may be quite varied and the finger for a given individual can present a very dry or a very wet surface, this then requires having a very broad acceptance range for the measured impedance; a broad acceptance range obviously makes fraud easier.

The detection of blood (pulse, level of oxygen in the hemoglobin) by optical means (light-emitting diodes with an adapted wavelength + photodiode) would seem to offer an interesting solution, but it would be deceived by a film of a transparent malleable material placed on a real finger, that is by a malleable material having the appropriate infrared 'color'. In addition, it is necessary to wait for a full cardiac rhythm, which can be fairly long in the case of some athletic individuals, and thus not very practical.

A recognition technique based on the form of the heartbeat has already been proposed, but its performance has not yet been proved; this performance will not be as precise as those of digital fingerprints and this technique thus has no practical application at this time.

Moreover, techniques for pulse measurement are incompatible with the technique for capturing digital fingerprints via scanning such as are described in the patent FR 2 749 955, because scanning time is on the order of a half second, which is much less than a heartbeat.

In the patent proposal US 2002/0009213, a technique for spectral recognition of the skin, and more precisely of the dermis, is proposed for the identification of people. The precision of this technique has not yet been proved, and it is not likely to be superior to what is made possible by the recognition of digital fingerprints. It requires lighting the finger with several light-emitting diodes (LED) of different colors and analyzing the light transmitted by the skin at different distances by using some photodiodes to measure the characteristics of this light: the more significant the distance between the light source and the sensor, the more in-depth characteristics of the dermis can be obtained. In addition, certain bands of frequency (toward

the infra-red) are very sensitive to the presence of blood. The number of photodiodes and light-emitting diodes would be limited by the fact that they must be assembled individually and thus the associated cost would rise very quickly.

The present invention proposes using for the recognition of people an image sensor of digital fingerprints (in principal on a silicon chip), optical or not, associated with the spectral recognition of skin using fewer light-emitting elements (generally light-emitting diodes LED) than if spectral recognition were used alone.

The invention thus proposes a device for person recognition that has, at the same time, on a same base, a digital fingerprint image sensor and an information sensor for spectral transmissions related to the skin of the finger whose fingerprint is picked up by the image sensor.

For the spectral fingerprint, light-emitting diodes will preferably, but not necessarily, be used and, with the help of photodiodes for detecting the light transmitted through the finger coming from these light-emitting diodes, an image specific to each light-emitting diode will be obtained; these diodes will emit preferably at several different wavelengths, especially in the infra-red, and the combination of these images will offer a wealth of information for the recognition of a person since the skin (dermis and epidermis, but especially the dermis) presents spectral characteristics that vary from one individual to another. Detection photodiodes will preferably be arranged in a matrix to offer a collection of spectral information comparable to a specific spectral "fingerprint" for the individual.

The use of digital fingerprints and spectral recognition of the skin will make it possible to obtain, on the whole, excellent levels of recognition and will, in particular, allow recognition of individuals for whom, in exceptional cases, the recognition of digital fingerprints would be unsuitable.

This sensor technique would be very difficult to deceive with a fake finger since it would be necessary to have, at the same time, the picture of the fingerprint to be counterfeited as well as a knowledge of the internal structure of the skin of the finger

of the individual possessing the fingerprint and of the spectral characteristics of this skin.

The presence of blood would also be detected as a wavelength in the near infra-red (in particular around 800nm which is the isobestis point between the oxyhemoglobin and the hemoglobin), which would be a strong indicator of a "live finger".

Fingerprint image capture and spectral information capture would happen either sequentially or simultaneously, this last being preferable. The capture could also occur in an intertwined way: partial capture of a fingerprint image followed by a partial capture of spectral information, and, once again, partial capture of a fingerprint image, etc. with a verification of the coherence of the different captures, either between captures or after all of the captures.

The fingerprint image may be obtained either in a stationary way or dynamically, by optical, thermal or capacitive means, in particular. In stationary image capture, the finger remains still during the fingerprint reading. In a dynamic image capture or scanner capture, it is the finger that moves on the sensor or the sensor that moves underneath a still finger; the overall image is reconstructed on the basis of partial images issuing from a sensor having only a small number of lines of image points; the reconstruction is done through correlation between the partial images obtained successively in the course of the related movement.

The digital fingerprint image sensor is, in principal, on a silicon chip.

The photodiodes for the analysis of spectral information are preferably situated on the same chip as the digital fingerprint image sensor. The light-emitting diodes that offer the light source for obtaining spectral information are situated outside of the silicon chip for technological reasons (they are not, in principal, made from silicon).

For the same level of quality in person recognition, the fingerprint sensor may be smaller than that which would be necessary without spectral recognition.

The light-emitting diodes and the photodiodes may be arranged symmetrically with respect to an axis to carry out several tasks in different positions in an equivalent manner; particularly in arrangements of two or four symmetric sectors.

The photodiodes for capturing spectral information may be the same as those which, in a matrix arrangement, serve for capture of the fingerprint image.

Additionally, the invention proposes correlating the spectral information from the observed skin section with the slice of digital fingerprint that is observed at the same time. In effect, spectral recognition makes it possible to deduce certain parameters which will subsequently be compared with a certain bracket to rule out local variations of the skin. According to the position, located with the help of the digital imprint, it will be possible to verify that the skin presents the required characteristics in the right location, augmenting the precision of the verification and making the technique extremely difficult to counterfeit.

This technique can be used in the case of stationary capture but even more conveniently in the case of scanner capture which makes it possible to reduce costs (the silicon sensor will present a weaker surface) all the while saving a significant wealth of information.

The invention proposes that capture of digital fingerprints and spectral fingerprints be physically achieved, preferably, by the same photodiodes; measurements will be made sequentially or, better, simultaneously.

When the digital fingerprint and spectral fingerprint measurements are not simultaneous, whether or not this is physically done with the same photodiodes, the invention proposes intertwining the capture of digital fingerprints and the capture of spectral fingerprints to make fraud difficult. In effect, if the digital fingerprint were first read and then the spectral fingerprint were read after the digital fingerprint, it would potentially be possible to present a counterfeit fingerprint and then a spectral counterfeit. If the sequence of measurements is sufficiently rapid or intertwined - like reading a sector of a fingerprint, making a spectral measurement with a first LED, then reading another sector, making a second spectral measurement, etc... - then it

becomes impossible to defraud by presenting alternatively a false digital fingerprint and a false spectral fingerprint.

Other characteristics and advantages of the invention will become apparent on reading of the detailed description that follows and which refers to the attached drawings in which:

-- figure 1 represents the principle of the device according to the invention;

-- figure 2 represents the device in figure 1 viewed from above;

-- figure 3 represents an embodiment of the invention with photodiodes integrated on the same chip as the fingerprint image sensor;

-- figure 4 represents the sensor from figure 3 viewed from above;

-- figure 5 represents an embodiment of the sensor with four symmetrical sectors;

-- figure 6 represents an embodiment of the sensor with two symmetrical sectors;

-- figure 7 represents a sensor in which the image of the fingerprint is detected by displacement of the finger on the surface of the sensor.

We will use the abbreviation LED (from the English "electroluminescent diode" [light-emitting diode]) to designate the emitter of monochromatic or quasi-monochromatic light for spectral recognition, with the knowledge that it will most frequently be a light-emitting diode, but that it can be whatever kind of light emitter is adapted to this use (laser, white light with a filter ...). The light emission is preferably in the red and near infrared, for which there is both good light penetration into the interior of the skin, a good response for blood, as well as sufficient sensitivity for detectors attached to silicon.

The term photodiode is used to designate the light sensor that will convert received photons into an electric signal.

The capture of the spectrum of the skin requires measurement of the optical response of the skin to a light excitation for different optical wavelengths. It is necessary to avoid measuring the light directly reflected by

the surface or the superficial layers of the skin (stratum corneum). In fact, the information that is specific to each individual is situated in the structure of the dermis. It is thus necessary for the light source (LED) to be separated from the light sensor (photodiode) in such a way that only the light that has traveled through the skin will get to the sensor, by minimizing the fraction of light that can get directly, or through a simple reflection from the skin, from the LED to the sensor. The choice of the distance between light source and detector makes it possible to affect the reduction of the direct reflection.

Figure 1 represents, in cross-section, the principle of the invention in which the digital fingerprint sensor and the spectral fingerprint sensor share the surface on which the finger rests during the person recognition operation. The fingerprint sensor (optical or not) is a matrix sensor 10 made up of a silicon chip mounted on a substrate 20. A LED 12 is represented as well as a corresponding photodiode 14, mounted on the same substrate 20. In practice, there are several LEDs, preferably corresponding to different wavelengths, and several photodiodes.

The fingerprint sensor will preferably be smaller than the finger so as to make it possible for the skin to touch the spectral sensor at the same time so that the captures occur at one single "touch" of the user. Having a smaller fingerprint sensor markedly diminishes the its performance in recognition, particularly in relation to the fact that it is difficult to present exactly the same part of the fingerprint each time. This performance loss will be compensated for by the supplementary information brought by spectral recognition.

Figure 2 represents a view from above of a mixed sensor, with a superimposed image of the finger 22 placed on the sensor.

To lower the costs by lowering the total number of electronic elements involved, the most desirable approach will be to insert the photodiodes into the digital fingerprint sensor. This could be done, in particular, when the fingerprint sensor uses a silicon chip on the surface of which the finger is placed directly. In this case, the chip must be protected by a thin transparent protective layer (or a cutwork layer), which does not mask the photodiodes that detect the light of the LEDs.

Figure 3 represents, in cross-section, a version of the invention with photodiodes 14 incorporated into the silicon chip 10 constituting the digital fingerprint sensor. Figure 4 represents, in a view from above, the configuration of the mixed sensor from figure 3.

It is preferable to control the LEDs directly with the help of the silicon chip which can contain all of the electronics necessary for fingerprint detection and spectral information detection.

It is also possible to integrate the algorithm for person recognition onto the silicon chip; this would make the whole device even less costly. This algorithm will consist, most frequently, of a comparison of the present spectral measurements with a collection of spectral measurements associated with an individual (a simple comparison for identity verification) or several individuals (a multiple comparison for identification of one person among several).

One advantage of the technique for integrating diodes into the silicon fingerprint sensor is that it will be possible to have numerous photodiodes for spectral reading for the same cost, since this cost is related essentially to the silicon surface and not to the number of photodiodes -- something that is not the case with an assemblage of discrete elements.

Increasing the number of photodiodes for spectral reading makes it possible to reduce the number of LEDs while, at the same time, increasing precision in measurement.

In addition, this makes it possible to correlate local spectral information with the specific zone of the finger located by the digital fingerprint: this would make it extremely difficult to fabricate a fake finger and would increase the precision of the identification. The photodiodes can be inserted into each sector one wishes to characterize. Each sector can use its own play of LEDs so as to have identical topological configurations and to simplify analysis, but a single play of LEDs for all sectors could also be used. In this case, it would be advantageous to have as symmetrical a configuration as possible. It would be most desirable to use a guide for the finger so as to avoid rotation; this would simplify correlation analysis.

Figure 5 represents a mode of embodiment in which the fingerprint sensor (silicon chip) is divided into four symmetric zones, each having several photodiodes connected to LEDs arranged around the chip. Figure 6 represents another version with a division of the sensor into two symmetric zones with respect to a horizontal axis. The photodiodes are situated on either side of this axis, in the chip and the LEDs are preferably situated on the axis, on either side of the chip.

In a specific embodiment, in which the matrix of digital fingerprint detection is a matrix of photodiodes (optical reading of the fingerprint, stationary and with direct contact), it is foreseeable that these same photodiodes will also serve for detection of the spectral fingerprint. In this case, it is the LEDs that serve as the source of lighting to light the craters and valleys of the digital fingerprints; the photodiodes gather a luminous motif representing the digital fingerprint when all the LEDs are lit; additionally, for obtaining spectral information, it is foreseeable that the LEDs will emit at different wavelengths. Typically, with a configuration such as that in figure 6 in which the LEDs are aligned on either side of the matrix of photodiodes on the horizontal axis of symmetry of the matrix, we can assume that the photodiodes of the image detection matrix, situated on an arc of a circle 30 centered around a given LED 32, receive spectral information coming from a single depth of the dermis, constituting an aspect of overall spectral recognition that can be obtained from other LEDs. The different wavelengths of LEDs and the different positions of photodiodes in the matrix make it possible to define an overall spectral fingerprint.

Consequently, in this embodiment, several LEDs of different wavelengths will be placed around a stationary optical sensor for direct contact. They will have, in this case, two functions: on the one hand, all or some of the LEDs will be simultaneously lit so as to light the finger sufficiently to enable capture of the digital fingerprint with the help of the matrix of photodiodes connected to electronics adapted to this use. On the other hand, a single wavelength will be activated to make possible measurement of

the spectral fingerprint with the help of the same photodiodes that are connected to electronics adapted for this spectrum reading.

It will be possible to combine this arrangement of photodiodes with analysis of the previously mentioned correlation.

In general, if fingerprint capture and spectral capture are done sequentially, a counterfeiter with a fake digital fingerprint and a fake finger showing the right spectral characteristics could present, at the right moment, each of the two fakes. It is thus highly advantageous to make this very difficult and the present invention proposes intertwining the readings and/or making measurements several times: in this case, it would be possible to be certain of the coherence of the information that had been read.

The possibilities (although not limited to these) are as follows:

-- complete reading of the fingerprint, followed by spectral reading, and then again reading of the fingerprint, verifying that the two fingerprint images are identical (with no displacement between the two fingerprint readings)

-- partial reading of the fingerprint (for example, the upper right quarter), partial reading of the spectral fingerprint (for example reading in the blue band of frequency) and so on sequentially up to a complete reading of the other parts of the fingerprint sensor and of information corresponding to other wavelengths.

-- fingerprint reading in each frequency band, making possible simultaneous acquisition of the digital fingerprint and the spectral fingerprint.

If stationary capture of a digital fingerprint, in which the finger doesn't move during information acquisition, seems the simplest to use, it does, however, present the problem of using a silicon surface that is at least equal to the size of the captured fingerprint.

The technique for scanner capture has been proposed in patent FR2 749 955 in which the finger slides on a linear capture zone, the overall image being reconstituted from successive images recovered partially each in relation to the others. The invention is equally applicable in this case. Figure 7 represents a corresponding configuration with a mixed sensor, with a silicon chip in the form of a long bar, containing both several lines of photodiodes for

fingerprint image capture and photodiodes for spectral information capture, the light-emitting diodes being situated at the exterior of the silicon chip.

By using scanning, the intertwining of readings proposed above occurs naturally, for the readings must be done "on the fly" (otherwise it would be necessary to slide the finger twice, which would significantly reduce the benefits of the technique).

Use of the scanning technique brings a significant advantage to the correlation of the digital fingerprint with the spectral fingerprint. Indeed, it will be possible to make correlations directly on the level of fingerprint slices, precisely for the portion of skin in contact with the device at the moment the measurement is taken. Verification of coherence can be made between the digital fingerprint corresponding to a sector of the finger and spectrum information corresponding to this sector for the person one seeks to identify.

Spectral analysis can also be set off "on the fly" when a certain fingerprint section is detected, so as to arrive at a precise spectral analysis of specific section of the skin.

Equally, correlations may be made over a spatial (and temporal) delay, rather than directly, by evaluating the speed of the finger on the fly. The correlation may be made on a same sector of the finger or on different sectors.

The best embodiment of the invention will consist in using an optical fingerprint scanning sensor connected to spectral fingerprint capture, in which the photodiodes are actually the same. This minimizes the elements necessary for information acquisition, and thus costs.

It is possible to separate the LEDs that serve as the light source for the fingerprint capture (by arranging them uniformly to light the finger equally) from those which serve for spectral image capture. But it is less costly to share usage of the light-emitting diodes to make them play the two roles.

The following possibilities are also foreseen for the present invention:

-- the light-emitting diodes may be integrated, insofar as the technology permits, into the chip constituting the digital fingerprint sensor;

-- the digital fingerprint sensor can be an optical sensor, but may also be a sensor of capacity, thermal energy, pressure, or current;

-- if the sensor is optical, the light source may be used in common for digital fingerprint capture and for the capture of spectral information;

-- for capture of the spectral fingerprint, a wavelength suitable for detection of the blood in the finger, and/or the level of hemoglobin, may be used;

-- the finger may be guided by a finger guide to facilitate correlation between digital fingerprint capture and the measurement of spectral information;

-- the device may be used one or several times for more secure identification of a person: several fingers can be verified or the digital fingerprint on one finger can be verified and the spectral information on another finger can be verified.

CLAIMS

1. Person recognition device, having on a same base (20) both a digital fingerprint image sensor (10) and a sensor (12, 14) of information of spectral transmission related to the skin of the finger from which the fingerprint is picked up by the fingerprint image sensor.

2. Device according to claim 1, characterized in that the digital fingerprint sensor is a stationary sensor on which the finger remains immobile during fingerprint capture.

3. Device according to claim 1, characterized in that the fingerprint sensor is a scanning sensor that captures one line or a small number of lines of an image and has the means to allow reconstitution of an overall fingerprint image through correlation between partial images obtained in the course of the relative displacement of the finger and the sensor.

4. Device according to one of the preceding claims, characterized in that the digital fingerprint image sensor is situated on a silicon chip and the sensor of the information from spectral transmission is comprised of light-emitting diodes and photodiodes.

5. Device according to claim 4, characterized in that the photodiodes and eventually also the light-emitting diodes are located on the same chip as the fingerprint image sensor.

6. Device according to one of the claims 4 and 5, characterized in that the light-emitting diodes and the photodiodes are arranged symmetrically with respect to an axis.

7. Device according to one of the claims 1 through 6, characterized in that that digital fingerprint sensor and the sensor of spectral information are constructed so as to function in succession.

8. Device according to one of the claims 1 through 7, characterized in that the digital fingerprint sensor and the spectral information sensor are constructed so as to function in an intertwined manner.

9. Method for person recognition, characterized in that, using a same device comprised of a fingerprint image sensor and a spectral transmission information sensor, detection occurs simultaneously of a digital fingerprint image and spectral transmission information relating to the skin of the finger whose fingerprint is detected, and the fingerprint image and the spectral transmission information for person recognition are used at the same time.

10. Method according to claim 9, characterized in that the digital fingerprint sensor and the spectral information sensor function in succession.

11. Method according to one of the claims 9 and 10, characterized in that the fingerprint image sensor and the spectral information sensor function in an intertwined manner.

12. Method according to claim 11, characterized in that the complete digital fingerprint is read several times, and the complete spectral information is gathered several times, in an intertwined fashion and the coherence between the different information detected is verified.

13. Method according to claim 11, characterized in that a part of the digital fingerprint corresponding to a determinate sector of the finger is read, the spectral information corresponding to this sector is read, and subsequently a complete image of the fingerprint is reconstructed from the partial images.

14. Method according to claim 13, characterized in that the digital fingerprint corresponding to a sector of the finger is verified for its coherence with the spectral information corresponding to this sector or to another sector for the person one seeks to recognize.

15. Device according to one of the claims 1 through 8, characterized in that the fingerprint sensor is and optical, capacitive, or thermal sensor or a sensor that is sensitive to the passage of current in the finger, or a sensor that is sensitive to pressure.

16. Device according to one of the claims 1 through 8, characterized in that a same source of light serves both for the capture of a digital fingerprint and the capture of spectral information.

17. Device according to one of the claims 1 through 8, characterized in that the capture of spectral information consists of a measurement at a wavelength serving to detect blood and/or the level of oxygen in the hemoglobin.

Figures 1-7

INTERNATIONAL SEARCH REPORT (in English and in French)

International Application No. PCT/FR2004/000093